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File   9:Business & Industry(R) Jul/1994-2002/Jul 25
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File 621:Gale Group New Prod.Annou.(R) 1985-2002/Jul 26
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File 636:Gale Group Newsletter DB(TM) 1987-2002/Jul 26
         (c) 2002 The Gale Group
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File 610:Business Wire 1999-2002/Jul 26
         (c) 2002 Business Wire.
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         (c) 2002 The HW Wilson Co.
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         (c) 2002 The HW Wilson Co
File 370:Science 1996-1999/Jul W3
         (c) 1999 AAAS
File 264:DIALOG Defense Newsletters 1989-2002/Jul 25
         (c) 2002 The Dialog Corp.
File  20:Dialog Global Reporter 1997-2002/Jul 26
         (c) 2002 The Dialog Corp.
File 608:KR/T Bus.News. 1992-2002/Jul 26
         (c)2002 Knight Ridder/Tribune Bus News
File 112:UBM Industry News 1998-2002/Jul 26
         (c) 2002 United Business Media
File  16:Gale Group PROMT(R) 1990-2002/Jul 26
         (c) 2002 The Gale Group
File  47:Gale Group Magazine DB(TM) 1959-2002/Jul 26
         (c) 2002 The Gale group
File  80:TGG Aerospace/Def.Mkts(R) 1986-2002/Jul 26
         (c) 2002 The Gale Group
File 148:Gale Group Trade & Industry DB 1976-2002/Jul 26
         (c)2002 The Gale Group
File 634:San Jose Mercury  Jun 1985-2002/Jul 25
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         (c) 2002 ProQuest Info&Learning
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         (c) 2002 The Dialog Corp.
File 813:PR Newswire 1987-1999/Apr 30
         (c) 1999 PR Newswire Association Inc

Set     Items   Description
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S1	44988	LEDS OR LIGHT()(EMIT? OR EMISSION)()DIODE?
S2	1083	S1(3N)(PLURAL? OR MANY OR SEVERAL OR NUMEROUS OR MULTI OR -MULTIPLE)
S3	2397	(BACKLIGHT? OR BACK()LIGHT?)(S)DISPLAY?(S)(RGB OR RED()GRE-EN()BLUE OR COLOUR? OR COLOR?)
S4	33057	(RESISTANCE?(3N)VALUE? OR BRIGHTNESS OR INTENSIT?)(S)(PRED-ETERMIN? OR SPECIFIC OR SPECIFIED OR SET OR PRESELECT? OR PRE-SET OR PRE()(SELECT? OR SET OR DETERMIN? OR SELECT? OR SPECIF-IED))
S5	12941564	CURRENT? OR ELECTRICITY? OR VOLT? OR POWER()SOURCE?
S6	12777	PWM OR PULSE()WIDTH()MODULAT?
S7	17864	DUTY(3N)(CYCLE? OR VALUE?)
S8	3510671	S5(S)(CONTROL? OR MANAG? OR ADJUST? OR MODIF? OR ALTER? OR INCREASE? OR DECREAS?)
S9	232162	(WIRELESS OR WIRE()LESS OR IR OR INFRARED)(3N)(DEVICE? OR -UNIT??)
S10	987250	(MOBILE OR RADIO OR PORTABLE OR CELLULAR OR REMOTE OR WIRE-()LESS)(3N)(UNIT? OR DEVICE? ? OR APPARATUS OR TELEPHONE? ? OR TERMINAL?)
S11	794644	(WIRELESS OR CELL? OR MOBILE)()PHONE? OR CELLPHONE?
S12	1008914	PDA OR PERSONAL()DIGITAL()ASSISTANT? OR (POCKET OR PORTABLE OR PALM()TOP OR PALMTOP OR HAND()HELD OR HANDHELD)()(COMPUTE-R? OR DEVICE?) OR PALM OR NEWTON
S13	499	AU=(NAKAMURA T? OR NAKAMURA, T?)
S14	0	S2(S)S3(S)S4(S)S5
S15	6	S2(S)S3(S)S5
S16	0	S15 NOT PY=>2000
S17	2	RD S15 (unique items)
S18	2691	S1(S)S9:S12
S19	17	S18(S)S4
S20	14	S19(S)S5
S21	5	S20 NOT PY=>2000
S22	5	RD S21 (unique items)
S23	3	S5(S)S6(S)S7(S)S1
S24	3	S23 NOT (S15 OR S20)
S25	2	RD S24 (unique items)
S26	0	S13 AND S18
S27	0	S13 AND S1
S28	0	S13 AND S3
S29	168	S18(S)S8
S30	11	S29(S)S3
S31	8	S30 NOT (S23 OR S15 OR S20)
S32	2	S31 NOT PY=>2000
S33	2	RD S32 (unique items)

17/3,K/1 (Item 1 from file: 621)
DIALOG(R)File 621:Gale Group New Prod.Annou.(R)

03113711 Supplier Number: 82735618 (USE FORMAT 7 FOR FULLTEXT)
National Semiconductor Adds Six New White-LED Drivers to Broad Portable Power Portfolio; Power Management Products Bring White Light to Handhelds Simply And Efficiently.
PR Newswire, pSFM04911022002
Feb 11, 2002
Language: English Record Type: Fulltext
Document Type: Newswire; Trade
Word Count: 1290

... and LM2704 are magnetic boost DC/DC converters optimized to drive up to four white **LEDs** in series and **several** strings of series **LEDs** at once. All the LEDs in a particular string are driven with the same constant **current** resulting in consistent brightness and **color** among those LEDs. The capability to achieve consistent brightness and **color** among **several** white **LEDs** coupled with the capability to drive large numbers of white LEDs makes the LM270x devices ideal for driving either **display** LEDs or keypad **backlight** LEDs or both at once. The LM270x devices drive white LEDs more efficiently than any...

...achieves 85% efficiency delivering 20 mA at 20V. The LM2703 has a 300 mA peak **current** limit, and the LM2704 has a 600 mA peak **current** limit. Both devices are also applicable as general-purpose magnetic boost DC/DC converters. An...

17/3,K/2 (Item 1 from file: 20)
DIALOG(R)File 20:Dialog Global Reporter

21228581 (USE FORMAT 7 OR 9 FOR FULLTEXT)
National Semiconductor: National Semiconductor adds six new white LED drivers to broad portable power portfolio; Power management products bring white light to handhelds simply and efficiently
M2 PRESSWIRE
February 12, 2002
JOURNAL CODE: WMPR LANGUAGE: English RECORD TYPE: FULLTEXT
WORD COUNT: 1196

(USE FORMAT 7 OR 9 FOR FULLTEXT)

... at once. All the LEDs in a particular string are driven with the same constant **current** resulting in consistent brightness and **colour** among those LEDs. The capability to achieve consistent brightness and **colour** among **several** white **LEDs** coupled with the capability to drive large numbers of white LEDs makes the LM270x devices ideal for driving either **display** LEDs or keypad **backlight** LEDs or both at once.

The LM270x devices drive white LEDs more efficiently than any...

22/3,K/1 (Item 1 from file: 636)
DIALOG(R)File 636:Gale Group Newsletter DB(TM)

04070355 Supplier Number: 53561312 (USE FORMAT 7 FOR FULLTEXT)
IBM: IBM receives most U.S. patents for sixth consecutive year.
M2 Presswire, pNA
Jan 12, 1999
Language: English Record Type: Fulltext
Document Type: Newswire; Trade
Word Count: 1129

(USE FORMAT 7 FOR FULLTEXT)
TEXT:
...third of the technologies represented by these patents already show up in products and solutions **currently** available from IBM, and in 1999, many more will reach the marketplace both in IBM...

...Among the U.S. patents issued for IBM inventions in 1998 are: US 5739545: Organic **light emitting diodes** having transparent cathode structures. Organic **Light Emitting Diodes** (OLED) offer new applications for display technologies due to their **brightness** , high resolution, energy efficiency and cost effectiveness. This patent will lead to improved performance of...
...meeting the Government's requirements. US 5770881: SOI FET Design to Reduce Transient B polar **Current** . This patent is a critical component of IBM's Silicon on Insulator (SOI) technique, which...

...display data content. This user interface software allows content to be displayed based on the **specific** interests and information need of multiple users. For example, the system could be used to...

...would still be accessible on another device capable of displaying less data (such as a **personal digital assistant**). EDITOR'S NOTES IBM's Intellectual Property Network Site at www.ibm.com/patents offers...from IBM is available electronically on NEWSdesk, the online news network. If you are not **currently** accessing the service, it can be reached on the Internet at: http://www.newsdesk.com...

22/3,K/2 (Item 2 from file: 636)
DIALOG(R)File 636:Gale Group Newsletter DB(TM)

04070238 Supplier Number: 53561193 (USE FORMAT 7 FOR FULLTEXT)
IBM: IBM receives most US patents for sixth consecutive year.
M2 Presswire, pNA
Jan 12, 1999
Language: English Record Type: Fulltext
Document Type: Newswire; Trade
Word Count: 1010

(USE FORMAT 7 FOR FULLTEXT)
TEXT:
...third of the technologies represented by these patents already show up in products and solutions **currently** available from IBM, and in 1999, many more will reach the market place both in...

...PATENTS Among the U.S. patents issued for IBM inventions in 1998 are: US5739545: Organic **light emitting diodes** having transparent cathode structures Organic **Light Emitting Diodes** (OLED) offer new applications for display technologies due to their **brightness** , high resolution, energy efficiency and cost effectiveness. This patent will lead to improved performance of...
...approach to meeting the Government's requirements. US5770881: SOI FET Design to Reduce Transient Bipolar **Current** This patent is a critical component of IBM's Silicon on Insulator (SOI) technique, which...

...display data content This user interface software allows content to be displayed based on the **specific** interests and information needs of multiple users. For example, the system could be used to...

...would still be accessible on another device capable of displaying less data (such as a **personal digital assistant**). IBM's Intellectual Property Network Site at http:///www.ibm.com/patents offers free access...

22/3,K/3 (Item 3 from file: 636)
DIALOG(R)File 636:Gale Group Newsletter DB(TM)

03911363 Supplier Number: 50116436 (USE FORMAT 7 FOR FULLTEXT)
-IMP: IMP EL Driver IC boosts voltage & slashes supply current -- reduces supply current by 45%
M2 Presswire, pN/A
June 30, 1998
Language: English Record Type: Fulltext
Document Type: Newswire; Trade
Word Count: 917

(USE FORMAT 7 FOR FULLTEXT)
TEXT:
M2 PRESSWIRE-30 June 1998-IMP: IMP EL Driver IC boosts **voltage** and slashes supply **current** -- reduces supply **current** by 45 percent
(C)1994-98 M2 COMMUNICATIONS LTD RDATE:290698 IMP, Inc. (NASDAQ:IMPX...

...circuit (IC) for its growing Power Management Integrated Circuit product line. From a DC (direct **current**) input supply **voltage** of 2 **volts** to 6 **volts** , the IMP560 generates a 120 **volt** peak-to-peak AC (alternating **current**) drive signal that is needed to excite an electroluminescent lamp, at up to 45 percent...
...EL lamps are used to backlight LCDs (liquid crystal displays) and keypads in low-power **portable** personal communications devices, such as pagers, **mobile phones** and **personal digital assistants** (PDAs). "The IMP560 represents our first proprietary Electroluminescent (EL) lamp driver and offers 45 percent lower system supply **current** when compared to the IMP803," said Barry Wiley, vice president of marketing, sales and applications...

...small area EL lamps or where ambient light conditions are low, a lower lamp drive **voltage** produces a substantial power saving while maintaining necessary **brightness** levels." The IMP560 incorporates the four EL lamp driving functions on-chip. These are the boost switch-mode power supply, its high-frequency oscillator, the high- **voltage** H-bridge lamp driver and its low-frequency oscillator. By boosting a DC input **voltage** of 2 to 6 **volts** up to a maximum level of 120 **volts** peak-to-peak rather than 180 **volts** as does the IMP803, system **current** requirements are cut from 22 milliamperes to 12 milliamperes. Lamp drive **voltage** is internally limited to 120 **volts** peak-to-peak to save energy. Two external resistors allow both the switching regulator frequency...

...intermittently for a short time. For maximum battery life, a disable mode cuts quiescent supply **current** by 90 percent, down to 50 nanoamperes. Connecting the external boost frequency resistor to ground...

...electrode and a transparent front electrode. It is similar to a capacitor structure. An AC **voltage** across the electrodes generates a changing electric field within the phosphor, which causes the phosphors, typically powders of zinc sulfide, to emit light of **specific** wavelength or color. The AC **voltage** must be relatively high, typically 100 **volts** to 200 **volts** , for light emission to occur. If a direct **current** battery **power source** is available, an EL lamp driver, sometimes referred to as an inverter, must boost and convert the low DC **voltage** to a high- **voltage** AC drive signal. Electroluminescent Lamp Applications and Benefits Liquid Crystal Displays must be lighted for...

...evenly light an area without creating "bright-spots". Since EL lamps typically consume much less **current** than incandescent bulbs or **light emitting diodes** (**LEDs**), their low power consumption, low heat generation and flexibility make them ideal for battery powered portable applications. EL lamp backlighting applications include: keyless entry systems; audio/video equipment remote controllers; **PDA** keyboards and displays; timepieces and watches; LCD displays in **cellular phones** , pagers, and handheld Global Positioning Systems (GPS); face illumination for instrumentation; assistance lighting for buildings...

22/3,K/4 (Item 1 from file: 20)
DIALOG(R)File 20:Dialog Global Reporter

02950721
EL Lamp Driver Extends Battery Life of Portable Systems
BUSINESS WIRE
September 28, 1998
JOURNAL CODE: WBWE LANGUAGE: English RECORD TYPE: FULLTEXT
WORD COUNT: 935

...creating "bright-spots". Since EL lamps typically consume much less current than incandescent bulbs or **light emitting diodes** (**LEDs**), their low power consumption, low heat generation and flexibility make them ideal for battery powered portable applications. EL lamp backlighting applications include: keyless entry systems; audio/video equipment remote controllers; **PDA** keyboards and displays; timepieces and watches; LCD displays in **cellular phones** , pagers, and handheld Global Positioning Systems (GPS); face illumination for instrumentation; assistance lighting for buildings...

22/3,K/5 (Item 2 from file: 20)
DIALOG(R)File 20:Dialog Global Reporter

01324472 (USE FORMAT 7 OR 9 FOR FULLTEXT)
Inventor of The Year Competition Recognizes Inventors For Universal Display Corp.'s Proprietary Stacked Organic Light Emitting Diode Patent
BUSINESS WIRE
April 07, 1998 11:48
JOURNAL CODE: WBWE LANGUAGE: English RECORD TYPE: FULLTEXT
WORD COUNT: 840

... on top of each other rather than the conventional side-by-side architecture used in **current** televisions and displays, thus providing three times the resolution in the same area. This is...

... applications such as flat panel displays, lasers and light. The rapidly growing display market is **currently** estimated at $35 billion annually worldwide, comprised mostly of cathode ray tube (CRT) and liquid...

...technology is seen as a future replacement technology for CRTs and LCDs, due to their **brightness** , high resolution, energy efficiency and cost effectiveness. The company's proprietary technology centers around three...

... results to differ materially from those indicated by such forward-looking statements, including the matters **set** forth in the company's Annual Report for the year ended Dec. 31, 1997 on...
?

25/7,K/1 (Item 1 from file: 275)

02616032 SUPPLIER NUMBER: 87694982 (THIS IS THE FULL TEXT)
White-LED drivers shine: small ICs bring color displays to life without draining your budget, board space, or batteries. (tech trends).
Israelsohn, Joshua
EDN, 47, 12, 53(6)
May 30, 2002

TEXT:

THE SHIFT FROM monochrome to color displays in handheld and portable equipment has opened the market for white LEDs as small, affordable, broad-spectrum illumination sources. The affordability is a recent phenomenon, which, along with improved driver ICs and waveguide designs, has fueled the uptake rate of white LEDs, particularly in cell phones and PDAs, as recent sales trends in Japan and Europe show.

Battery-operated equipment that incorporates an LCD must provide an illumination source for good readability under most operating conditions. A color LCD requires a broad-spectrum illumination source. Candidates include CCFLs (cold-cathode fluorescent lamps), ELs (electroluminescent lamps), and white LEDs (see sidebar "Illuminating alternatives").

CCFLs and ELs require high-voltage ac excitation of several hundred volts operating at frequencies of 0.5 to 40 kHz (Reference 1). Inverter circuits that drive these illuminators from battery power are not complex, but you must factor in their cost and board area to determine the total cost of ownership for your design. Depending on your application, you may also have to contend with noise coupling to other circuits from the high-voltage inverter, lamp, and leads.

The third choice, the white LED, operates with low-voltage dc. Though many designs still require inverters to strike, say, a string of LEDs from the available battery voltage, the inverter's operating frequency does not influence the LED's performance--potentially an important degree of freedom in your design. Low-voltage lighting devices and design rules may allow you to save driver-component cost and board space but, depending on the supply voltages available, can challenge you to devise an energy-efficient approach to panel illumination.

LIGHT 'EM IF YOU GOT 'EM

Most LCD-illumination applications require a brightness control that allows an end user to adjust the display to compensate for ambient lighting. Because LED photon emission results from electron-hole pair recombination, the emission rate and, thus, the perceived brightness are proportional to the forward diode current. Continuous-time current control, although perhaps the simplest approach to setting the brightness, gives poor color consistency over the brightness range due to the fact that the LED's color temperature depends on its operating current. Uses that don't require high color fidelity, such as button illumination, can use the diode-excitation current to control brightness. But designs that require good color fidelity over a brightness range avoid the color-shift problem by exciting the LEDs with a pulse-width-modulated source.

Some applications, such as automotive-cabin electronics, have access to sufficient **voltage** to strike multiple series-connected **LEDs** . In these cases, a **PWM** circuit with an open collector or a **current** -mirror output can form a simple LED drive (Figure 1). In this example, a DCP (digitally controlled potentiometer), I(C.sub.1), serves as the brightness-control circuit's digital interface. (R.sub.1) and (C.sub.1) set the basic clock rate through a monostable multivibrator, I(C.sub.2A). The DCP in series with (R.sub.2) work in conjunction with (C.sub.2) to set the **duty cycle** of I(C.sub.2B). Specifically, the circuit's **duty cycle** is equal to the ratio of the RC time constants
((R.sub.2)+(R.sub.IC1))(C.sub.2)/(R.sub.1)(C.sub.1) (Reference 2).

(FIGURE 1 OMITTED)

Although this circuit is not typical of LED drivers for applications operating on supplies much less than 12V nominal, it raises some useful points about driving white LEDs in general. Most designs that use multiple LEDs to illuminate a display require reasonably well-matched devices to

ensure that the LCD brightness remains even across its entire surface. White-LED-manufacturing processes have matured to the extent that devices from the same lot match fairly well when you excite them with equal currents. If you don't mix lots, you can connect LEDs in series up to the compliance voltage of your driver and get even brightness.

If the series sum of forward-diode voltages exceeds your driver's compliance-voltage range, you must resort to a parallel-drive arrangement. Typical of single-junction devices, white LEDs have poorly matched forward voltages, so simply wiring devices in parallel leads to large differences in forward current and, as a result, differences in brightness. To compensate, ballast resistors provide negative feedback for each parallel device (Figure 2a). Should one LED pass more current than the other, the voltage drop across its ballast resistor increases, pushing the device back down its I/V curve.

(FIGURE 2 OMITTED)

The alternative is to drive parallel LEDs with regulated current sinks such as the MAX1916 from Maxim Integrated Products or the LX1190 from Microsemi. The advantage of a regulated current sink, such as the 1916, is that, unlike ballast resistors, it gives constant brightness independently of the supply voltage.

The MAX1916 allows you to set the LED brightness either by adjusting the current into the SET pin or by driving a pulse-width-modulated signal to the enable pin. The SET current, which can range from 5 to 260 (micro)A, is mirrored through a nominal ratio of 230, resulting in three individual LED-excitation currents of about 1 to 60 mA (Figure 2b).

The enable pin supplies a maximum of 100 (micro)A to power the on-chip reference, error amplifier, and undervoltage-lock-out circuit. The driver operates from 2.5 to 5.5V sources and draws 1 (micro)A or less in shutdown mode. The 99-cent (1000) MAX1916 features on-chip thermal protection and is available in a SOT-23-6.

The Microsemi LX1990 can sink 0.1 to 30 mA through two LEDs with a 400-mV dropout voltage. An on-chip reference provides current for an external current-set resistor. The set current is 1% of the sink current, allowing you to use convenient resistor values and a small control current. A PWM signal can adjust the brightness over a 500-to-1 range. The manufacturer rates the current-sink outputs to 12V maximum. The 1990's maximum quiescent current is 4 mA and drops to 1 (micro)A in shutdown mode. The 64-cent (250), dual-channel current sink is available in an MLP-6.

PUMP UP THE DRIVE

The large number of portable devices powered by single lithium cells cannot directly power white LEDs because the diode drop can be as large as 4V. Driver ICs that boost and regulate the battery voltage can be open- or closed-loop controllers, charge pumps, or inductive converters with voltage or current outputs.

Keep a couple of issues in mind when comparing the merits of the various designs. Efficiency ratings can be misleading, especially when comparing drivers based on different converter topologies. Manufacturers express most efficiency measurements as a ratio of output power to input power. But the brightness of the LED is proportional to its current. The forward voltage can vary several hundred millivolts. Whether your driver establishes a fixed voltage for use with ballast resistors or a current source with an upper compliance limit, a shift in forward diode voltage changes the proportion of the power dissipated in the LED and in the driver. But from your battery's perspective, it matters little if you are dissipating power in the LED, in a current mirror internal to the driver, or in a ballast resistor. Comparing driver input power for a given LED forward current is a more reliable way of comparing the energy usage of dissimilar drive circuits (Reference 3).

Conceptually, the simplest driver is an open-loop voltage-output charge pump. National Semiconductor's LM3354 buck/boost switched capacitor converter is an example of this type of driver (Figure 3a). The 3354 operates from 2.5 to 5.5V supplies and is available in a range of output voltages. The 4.1V-output option is the most appropriate for driving white LEDs. The converter operates at a typical switching frequency of 1 MHz, which allows you to use small capacitors but requires you to carefully design your layout. You should mount the capacitors as close as possible to the driver's pins and use short connections to a ground plane.

(FIGURE 3 OMITTED)

Typical of drivers of this sort, they allow you to control the LED brightness by applying a PWM control signal to the shutdown pin. The PWM signal should have a repetition rate of at least 60 Hz to prevent flicker but should not exceed 200 Hz to allow the capacitors to discharge. Although the 3354's idle current is 475 (micro)A, which drops to 5 (micro)A in shutdown, it can source 90 mA to its load. On-chip overtemperature protection prevents the device from damage should operating conditions cause excess power dissipation. The $1.20 (1000) converter is available in an MSOP-10 package.

The LTC3200-5 from Linear Technology fits into a SOT-23-6 and outputs 5V from a 3 to 4.4V battery voltage. The six-pin device requires only one pump capacitor, further reducing the size of your layout for as many as five LEDs (Figure 3b). The 3200-5 operates at 2 MHz and can source as much as 100 mA. It draws a maximum of 8 mA during normal operation and less than 1 (micro)A in shutdown. The $1.60 (1000) 3200-5 requires three relatively small external capacitors yet offers low output ripple. However, its higher output voltage results in somewhat greater power dissipation in its external ballast resistors than some of its competitors for a given LED forward current.

Semtech also offers a charge-pump driver in an MSOP-10 package. The SC600 is available is several versions covering 4 and 4.5V outputs at 120 mA and 4.5 and 5V at 60 mA. Pin-strapping options allow you to choose among four clock rates from 8 to 650 kHz with operating and output currents rising to the clock speed.

While its battery voltage remains above a threshold, the SC600 connects its pump capacitors as a 3/2 pump--a more energy efficient topology than the doubler connection it uses when the battery voltage falls below the threshold. The threshold voltage has about 80 mV of hysteresis to prevent mode chatter, which would cause large a large ripple voltage on the output. At its highest clock rate, the $1.40 (1000) driver draws 2.5 mA in quiescent current. The part requires four external capacitors, ballast resistors for the LEDs, and an input supply of 2.7 to 6.5V.

KEEPING CURRENT

As noted earlier, a current-regulated source results in an LED drive that remains comparatively constant in the face of supply-voltage fluctuations. Several charge-pump drivers provide current regulation, though not all implement the regulator in the same way.

One way of sensing the current, typified by the LTC3202 from Linear Technology, is to sense the voltage dropped across one of the ballast resistors (Figure 4). Operating at 1.5 MHz, this 3/2 pump can source as much as 125 mA from a 2.7 to 4.5V input supply. The $1.90 (1000) driver uses four capacitors, including two flying ceramic capacitors in the self-clocked pump circuit. You can pin-strap-program the feedback threshold voltage to 200, 400, or 600 mV. A fourth pin-strap combination invokes the shutdown mode. As with other drivers, toggling the shutdown mode with a pulse-width-modulated signal allows you to dim the LEDs without substantially shifting their color balance. The LTC3202 is available in an MSOP-10 and can drive as many as eight white LEDs.

(FIGURE 4 OMITTED)

Maxim's MAX1912 is also a 3/2 charge pump that uses voltage feedback from a ballast resistor to close a current-source control loop around the LEDs. This $1.05 (1000) IC can deliver 60 mA with a 200-mV-feedback overhead. The 1912 is self-clocking at 750 kHz and, like the LTC3202, requires two flying capacitors in the pump circuit as well as input and output bypass capacitors. You can reduce the charge-pump-induced supply ripple by forming a C-R-C (pi) filter on the input pin of the MSOP-10 package.

Another pair of charge-pumped current-regulated drivers comes from National Semiconductor and Seiko Instruments. Both use internal current mirrors to regulate the LED forward current. The current mirrors eliminate the need for ballast resistors, which simplifies your layout, but increases the on-chip dissipation. National's LM2794 can drive one to four LEDs with as much as 20 mA each. The current mirror ratio is 1-to-10, allowing you to set the regulated current with an external resistor of several hundred ohms. You can adjust the LED brightness by either shifting the feedback threshold voltage with an externally generated current or by applying a PWM control signal to the shutdown pin.

The chip operates from supplies of 2.7 to 5.5V but switches from a

charge-pump to pass-through mode at about 4.7V. Again, there's about a 0.25V of hysteresis on the pass-through-mode threshold to prevent excess output ripple induced by mode chatter.

The $1.30 (1000) LM2794 is among the smallest drivers available. It is available in a 14-bump micro-SMD package measuring slightly more than 2 x 2.4 x 0.84 mm. It self-clocks at a minimum of 325 kHz and operates with four external 1-(micro)F capacitors.

The S8813 from Seiko Instruments is a doubling charge pump with a three-channel mirror. Like the LM2794, an external resistor sets the S8813's output current, in this case to 5 to 18 mA per channel. The Seiko driver operates from 2.7 to 4.5V supplies. The S8813 pump frequency is typically 600 kHz, but it uses a pulse-frequency-modulated charge pump to regulate its output. This arrangement may offer benefits with regard to energy usage, but it can also complicate noise management in your design. The current mirrors match to within 1%, and the overall mirror accuracy is 5%. The $1.20 (10,000) driver comes in an SON10 package.

I GET A KICK OUT OF (micro)

Flying capacitors are not the only way to boost the battery voltage. A number of drivers use inductive kickback to develop between several and tens of volts to light series strings of white LEDs (Figure 5). Converters of this type pull inductor current through an internal switch, usually an N-channel MOSFET. During the time interval when the switch is on, energy is stored in the inductor's magnetic field. When the controller turns the switch off, the inductor voltage rises as the collapsing magnetic field induces a current that drives the load.

(FIGURE 5 OMITTED)

Inductive step-up converters that operate at high clock rates can use low-profile, off-the-shelf inductors--many only 1 mm tall. If this type of converter has a disadvantage, and this drawback applies to any topology that directly senses and servos the diode current, it is that you need to use small-value sense resistors. This situation is particularly true for those converters that operate on low feedback voltages.

The MAX1848 from Maxim is such a device. Like many others of this type, it provides an on-chip MOSFET to switch a small external inductor. The IC drives either two or three series-connected LEDs from a 2.6 to 5.5V source. A small-value current-sense resistor provides feedback to a servo amplifier that controls the output voltage for constant diode current. The driver can develop a drive output as large as 13V.

The 1848 has a 1.2-MHz nominal clocking frequency, which allows you to drive multiple LEDs while using a small inductor and filter capacitor. It can drive parallel strings of series LEDs to a maximum of six diodes, albeit with three sense resistors and less than perfect current matching. The MAX1848 costs $1.25 (1000) and is available in a SOT-23-8.

Linear Technology's LT1937 can drive six white LEDs in a single string, thanks to its on-chip 36V switch. The choice of sense resistor programs the nominal current over a range of 5 to 20 mA while requiring less than 100-mV-output overhead for feedback. You can implement a dimming circuit by summing a control current at the feedback node or by applying a PWM control signal at the shutdown pin. If you set the $1.30 (1000) driver to a nominal 15 mA, you can dim down to 4 mA with a 4.2V input supply without resorting to pulse-skipping, and it can maintain regulation down to zero diode current. The LT1937 is available in SC70-6 or SOT-23-5 packages.

National Semiconductor's LM2704 can source 20 mA with a compliance voltage of 20V from a 2.2 to 7V supply--enough to drive eight white LEDs in two parallel strings. Its own circuitry draws a maximum of only 300 (micro)A over temperature; in shutdown, it draws 2.5 (micro)A.

The LM2704's inductor switch has an (R.sub.ON) of 0.7 (ohm), which helps keep the device's internal dissipation small--an important factor for a SOT-23-5 converter--and the conversion efficiency high. The result is a switch that can pass peak currents of more than 0.5A. The LM2704 costs 90 cents (1000). A similar converter, the LM2703, supplies a 15-mA load current with a compliance voltage of 20V and costs 85 cents (1000).

Microsemi's LX1993 operates on a quiescent draw of no more than 100 (micro)A but drives a series string of four white LEDs to 20 mA. It can operate on a battery voltage of 1.6 to 6V. Mounted in an MSOP-8, this $1.40 (250) converter has an internal inductor switch with a typical (R.sub.ON) of 1.17 (ohm). A related controller, the $1.01 (250) LX1992 uses an external N-channel MOSFET, allowing you match the switch's characteristics

to the needs of your application.

DOING MORE WITH LESS

Recent advances have not been limited to the driver electronics. White-LED manufacturers have been improving their products by increasing their conversion efficiencies and part-to-part consistency. A number of factors determine a diode's brightness at a given current. A white LED starts life as a blue LED. The blue LED's short-wavelength light excites a phosphor coating that the manufacturer applies to the inner surface of the output lens. The phosphor re-emits the LED's energy over a broad spectrum. Each part of the device--blue LED, phosphor coating, and lens--contribute to the energy conversion efficiency and the resulting brightness.

Nichia's NSCW215 series of white LEDs boasts greater conversion efficiency than that of previous generations, increasing the brightness by as much as 50%. The company has also developed new packages for large-area devices that operate at high forward currents. These devices, operating on several hundred milliamperes of forward current, are challenging other light sources in channel-letter displays, traffic signals, and other applications in which good daylight readability is a requirement.

Improvements in waveguide designs have also prompted OEMs using small monochrome displays to consider white LEDs in place of alternatives such as CCFLs and EL sources. Manufacturers such as Global Lighting Technologies have developed inexpensive light guides that allow OEMs to evenly light displays with fewer diodes. A dense array of molded reflectors in the guide's rear surface mirror light from a few edge-mounted LEDs. The result is an even, well-diffused light source that is adequate for displays used in handheld instruments and PDAs.

Rather than assemble your own display from LCD, backlighting diodes, driver electronics, reflectors, and mounting hardware, you may prefer a preassembled unit, such as the 240 x 64-pixel MTG-F24064 FMNHSGW LCD module from WTS. This display is edge-lit by white LEDs and includes a Toshiba T6963C display controller. With an optional power converter, the display and backlight operate from a single-supply 5V source. The $44 (1000) display features a 132 x 39-mm viewing area and a 0.51-mm dot pitch. The company also makes TFT (thin-film-transistor) color displays.

AT A GLANCE

* White-LED-driver ICs can take a number of forms: open- or closed-loop, inductive or charge pump, or voltage- or current-output converters.
* Different topologies make comparing "efficiency" difficult at best and dubious at worst. Your best bet is to compare input power for a given diode current.
* Finding the best driver for your application is complicated by necessary trade-offs among size, external component count, energy usage, and operating range.
* Consider the characteristics of the LEDs, driver electronics, and light guides, if any, as a system to find optimization opportunities.

ACKNOWLEDGEMENTS

Thanks to Brian Conner of National Semiconductor, Karl Volk of Maxim Integrated Products, and Tony Armstrong of Linear Technology for their contributions to this article.

FOR MORE INFORMATION ...

For more information on products such as those discussed in this article, go to www.ednmag.com/info and enter the reader service number. When you contact any of the following manufacturers directly, please let them know you read about their products in EDN.

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REFERENCES

(1.) Lizotte, Brad, "LCD backlighting technologies.... which one is best for you?" ECN, Jan 1, 2001.

(2.) Martinez, Carlos, "Low cost PWM circuit for white LED drive," AN108-1, Xicor, April 2002.

(3.) Conner, Brian, "Driving white and blue LEDs in handheld portable electronics," National Semiconductor, 2002.

RELATED ARTICLE: Illuminating alternatives.

CCFLs (cold-cathode fluorescent lamps) are line emitters and enjoy relatively high efficiency and light output. They dominate backlighting applications for displays larger than about 6 in. diagonal, such as those

that laptop computers use. Small CCFL tubes measure about 1/8 in. in diameter, but they require protection from shock, which can complicate the mechanical-mounting design and increase the overall panel thickness. Beyond the issue of physical dimensions and mounting concerns, CCFLs' low shock tolerance renders the parts too fragile for use in "droppables"--cell phones, PDAs, and handheld meters--without additional provisions in the mechanical design.

CCFLs are difficult to start at cold temperatures. For outdoor use, their controllers must make allowances for the ambient temperature as part of controlling the starting voltage. In severe cases, a design may need to include a heating element to raise the CCFL's temperature to within a workable range.

ELs (electroluminescent lamps) are less than 40 mils thick. They are surface emitters, which results in efficient, even lighting without diffusers, reflectors, or waveguides. They consume less power than LEDs and thus dissipate less heat.

Both CCFLs and ELs require high-voltage ac excitation. As a result, both the power converters and the lamps themselves can emit EMI. If mounted adjacent to wireless receivers or other sensitive circuits, either light source may require additional shielding.

You can reach Technical Editor Joshua Israelsohn at 1-617-558-4427, fax 1-617-558-4470, e-mail jisraelsohn@ cahners.com.

... pulse-width-modulated source.

Some applications, such as automotive-cabin electronics, have access to sufficient **voltage** to strike multiple series-connected **LEDs** . In these cases, a **PWM** circuit with an open collector or a **current** -mirror output can form a simple LED drive (Figure 1). In this example, a DCP...

...series with (R.sub.2) work in conjunction with (C.sub.2) to set the **duty cycle** of I(C.sub.2B). Specifically, the circuit's **duty cycle** is equal to the ratio of the RC time constants ((R.sub.2)+(R.sub...

25/7,K/2 (Item 1 from file: 148)

12905189 SUPPLIER NUMBER: 68146169 (THIS IS THE FULL TEXT)

Economical circuit drives white LEDs.(Technology Information)

Wells, Eddy

EDN, 45, 24, 160
Nov 23, 2000

TEXT:

NEWLY AVAILABLE white **LEDs** are replacing CCFLs (cold-cathode fluorescent lamps) in handheld applications using a backlit LCD. These applications include PDAs (personal digital assistants), digital cameras, and cellular telephones, to name a few. Advantages of white **LEDs** over CCFLs include longer life, higher efficiency, and significantly lower operating **voltages** . Regulating the **current** in the LED (typically 10 to 30 mA) controls the brightness; the forward **voltage** in each LED is approximately 3V. The circuit in Figure 1 provides a means of efficiently controlling LED **current** in a series-connected string. The TL5001 **PWM** -controller IC is an older, industry-standard, inexpensive driver. The boost topology of the circuit allows operation from a single or dual lithium-ion cell. The ratings of (Q.sub.3), (SD.sub.1), and the maximum allowed **duty cycle** of the IC (programmed with pin DTC) determine the maximum output **voltage** of the circuit. (V.sub.CC) comes from a separate 5V supply.

(Figure 1 ILLUSTRATION OMITTED)

Trade-offs in the selection of inductor (L.sub.1) include size, dc resistance, and inductance value. An 82-(micro)H inductor (with 200-m(Omega) dc resistance) results in continuous inductor current at higher LED currents, but the current becomes discontinuous at lower levels. The RT pin programs the oscillation frequency at approximately 200 kHz. Because the TL-5001 has a relatively weak (20-mA) open-collector output

driver and is intended to drive a buck-topology circuit, the circuit uses a low-cost inverter stage comprising (Q.sub.1) and (Q.sub.2) to efficiently drive (Q.sub.3). (R.sub.6) provides controlled turn-on and fast turn-off for (Q.sub.3). The reverse-breakdown voltage of (SD.sub.1) must be greater than the (C.sub.2)-filtered (V.sub.OVT).

(R.sub.7) senses current in the white-LED string; the error amplifier at the FB pin of the IC controls the feedback signal at this pin to 1V. You can control the LEDs' intensity by summing in a control voltage via (R.sub.4). Figure 2 shows the efficiency of a four-LED string. You could obtain approximately 2% higher efficiency by adding a gain-of-5 op-amp stage between (R.sub.7) and (R.sub.3), resulting in a lower voltage drop across (R.sub.7). Of course, this slight efficiency improvement adds to the system cost. For higher power applications, such as notebook computers, you can attach additional LED strings to (V.sub.OUT). To maintain uniform intensity in each string, you should add a dummy resistor of the same value as (R.sub.7) to each string.

(Figure 2 ILLUSTRATION OMITTED)

Is this the best Design Idea in this issue? Vote at www.ednmag.com/edn mag/vote.asp.

Eddy Wells, Texas Instruments

TEXT:

NEWLY AVAILABLE white **LEDs** are replacing CCFLs (cold-cathode fluorescent lamps) in handheld applications using a backlit LCD. These...

...personal digital assistants), digital cameras, and cellular telephones, to name a few. Advantages of white **LEDs** over CCFLs include longer life, higher efficiency, and significantly lower operating **voltages** . Regulating the **current** in the LED (typically 10 to 30 mA) controls the brightness; the forward **voltage** in each LED is approximately 3V. The circuit in Figure 1 provides a means of efficiently controlling LED **current** in a series-connected string. The TL5001 **PWM** -controller IC is an older, industry-standard, inexpensive driver. The boost topology of the circuit...

...ion cell. The ratings of (Q.sub.3), (SD.sub.1), and the maximum allowed **duty cycle** of the IC (programmed with pin DTC) determine the maximum output **voltage** of the circuit. (V.sub.CC) comes from a separate 5V supply.

33/3,K/1 (Item 1 from file: 370)
DIALOG(R)File 370:Science

00500619 (USE 9 FOR FULLTEXT)
Organic Electroluminescent Devices
Sheats, James R.; Antoniadis, Homer; Hueschen, Mark; Leonard, William; Miller, Jeff; Moon, Ron; Roitman, Daniel; Stocking, Andrew
The authors are at Hewlett Packard Laboratories, 3500 Deer Creek Road, Palo Alto, CA 94304, USA.
Science Vol. 273 5277 pp. 884
Publication Date: 8-16-1996 (960816) Publication Year: 1996
Document Type: Journal ISSN: 0036-8075
Language: English
Section Heading: Articles
Word Count: 4438

(THIS IS THE FULLTEXT)

...Text: Applications and Design Goals Inorganic emissive **display** sources. The development of LED efficiency since the early 1960s is illustrated in Fig. 3...

...reviewed recently by Moon (B1) . The most prevalent of these today for small flat-panel **displays** is based on vacuum fluorescence, which is essentially a flattened cathode ray tube. The luminous efficiency is about 1 lm/W, and drive **voltage** is 30 to 50 V. Flat-panel **displays** are long-lived and rugged; however, larger sizes require supports to prevent window collapse, which **increases** cost. Plasma **displays** (which use phosphors for multicolor operation) do not face this limitation and are similarly long-lived, but they operate at even higher **voltages** (100 to 200 V) and attain lower efficiencies (~0.2 lm/W); **color** operation lowers efficiency further. EL from II-VI compounds (for example, Mn-doped ZnS) is ...

...driven), which, however, requires 200-to 300-V bias and is not available in all **colors** at reasonable efficiencies. All of these systems except plasmas have some difficulty achieving good uniformity over large areas. Field emission **displays** (similar to vacuum fluorescence but with cold cathodes) are under development but have not reached...

...Polymer-dispersed liquid crystals (PDLCs) with **backlighting** from vacuum fluorescence represent another important competitor (B35) . Conventional liquid crystals (which make up ~85% of the **current** flat-panel **display** market) suffer both from substantial driver costs (for active matrix systems) and low efficiency (because...
...waste up to 85 to 90% of the light); PDLCs do not require polarization. They **currently** require **voltages** of ~10 to 20 V...

...Inorganic **LEDs** would seem ideal in all respects: They have excellent (eta) .inf(el), bias of only a few **volts** , availability in all **colors** , and superb reliability. There is only one major problem-cost. **Displays** must be assembled from individual **color** -matched **LEDs** into the correct position and wire bonded; this is prohibitive for more than about 10...

...Applications and requirements. **Displays** can range in complexity from a single pixel (such as an instrument lamp or a picture) to a high-resolution computer monitor (**currently** 1.3 x 10.sup(6) three- **color** pixels). The luminance of a cathode ray tube is ~100 cd m.sup(-2). Power efficiency requirements are more severe if the **display** is to be battery-powered and if it is to be used outdoors. Bias **voltage** should be compatible with the battery (<=9 V) to avoid the cost of **voltage** upconverters...

...Lifetime and environmental specifications also differ according to usage. A desktop **display** should have an operating lifetime of at least a few years but will typically reside in a temperature- **controlled** environment. Portable appliances, on the other hand (such as **cellular**

phones or **palmtop computers**), may be off during much of the product life, but they must withstand extremes of...also be stable under these conditions. Although the hermeticity requirement may be greater for organic **LEDs** (OLEDs), most other systems, including liquid crystals, require similar sealing...

...From these considerations, the appropriate near-term target for OLEDs is most likely **displays** of ~10 to 1000 characters. (Although greater pixel counts may someday be practical, the difficulties are formidable, especially for full- **color displays** , and much work needs to be done to assess them.) Considering commercial surveys of the...

...Monochrome operation will be acceptable for these initial applications, but full- **color** operation is desirable and eventually essential. There are three ways of achieving this: (i) evaporation...

...angles against walls of different heights to determine the spatial distribution of compositions emitting different **colors** (B36) ; (ii) construction (by plasma etching) of Fabry-Perot microcavities whose length determines the emission...

...blue emission to green and red by means of energy transfer to dyes in a " **color** conversion layer" interposed between the emitter and ITO (B38) (B39...

33/3,K/2 (Item 1 from file: 16)
DIALOG(R)File 16:Gale Group PROMT(R)

04361418 Supplier Number: 46396657 (USE FORMAT 7 FOR FULLTEXT)
HP ANNOUNCES TWO SURFACE-MOUNT LED SERIES WITH HP'S BRIGHTEST AND SMALLEST COMPONENTS
News Release, pN/A
May 20, 1996
Language: English Record Type: Fulltext
Document Type: Magazine/Journal; Trade
Word Count: 700

(USE FORMAT 7 FOR FULLTEXT)
TEXT:
...Calif., May 20, 1996 -- Hewlett-Packard Company today announced two new surface-mount series of **light emitting diodes** (**LEDs**) for applications such as telecommunications, data communications and consumer electronics, which require the brightest and...

...an advanced manufacturing process designed to improve product reliability and design. HP's SunPower Chip **LEDs** with aluminum indium gallium phosphide (AlInGaP) material and the surface-mount flip-chip LED series...
...customers more reliable, less expensive and more energy-efficient products. HP's new surface-mount **LEDs** also have versatile **colors** and packaging that make them ideal illumination sources for applications in keypad and liquid-crystal **backlighting** and panel indicators, particularly for those used in battery-operated, handheld **cellular telephones** , personal communicators and laptop computers. "HP is helping to shape the global communications market," said Milt Liebhaber, general **manager** of HP's Optoelectronics Division. "We are working to offer clear solutions for the exploding information age. With these new families of **LEDs** and the flip-chip process, our customers can find better ways to design smaller, more...

...expensively. We're improving design and dropping prices at the same time." HP's new **LEDs** are available in industry-standard configurations for use in compact PC boards. The high-brightness...

...available in a right-anglepackage, which is excellent for side-lighting applications, such as LCD **displays** in pagers, PDAs and telephones. HP

SunPower Chip LED Series Using HP's AllnGaP material, the new HP SunPower Chip LED series provides high brightness in three **colors** : amber, orange and reddish-orange. The **LEDs** have luminous intensities of 65 mcd at 20 mA for amber and orange and 50 mcd for reddish-orange -- all typical at 20 mA drive **current** . This is combined with very high luminous efficiency. This means, for example, that designers and manufacturers need only four of the new **LEDs** instead of 12 gallium phosphide (GAP) **LEDs** to achieve the same or brighter illumination in a typical **backlighting** application, such as **cellular telephones** . The consumption of **current** is reduced by a factor of three (120 vs. 40 mA). Even though the expected...

...the new HP SunPower Chip LED series is about twice that of conventional surface-mount **LEDs** , the total cost to provide equivalent illumination is expected to be about a third less. Flip-chip **LEDs** : HSMX-H670/690 Series HP's flip-chip **LEDs** are manufactured with a new process that eliminates the expensive wire-bond process and, instead...

...the expensive and fragile wire parts, also reduces size and packaging constraints. HP flip-chip **LEDs** are excellent for applications not requiring the extra-high brightness and efficiency of AllnGaP. The HP HSMX-H670/690 series has many of the same features as the SunPower Chip **LEDs** . In addition, the series has the smallest height (.6mm) and uses HP's proven high-efficiency GaAsP/GaP (gallium arsenide phosphide on a gallium phosphide substrate) in the **colors** of red, orange and yellow and gallium phosphide (GAP) green. This series offers solutions for customers who want versatile **colors** , high reliability and low cost. HP's New Flip-chip Process HP has found no...

...chip production eliminates the problem of broken bond wires -- a major source of failure in **LEDs** that are subject to temperature cycling. The result is that the new flip-chip **LEDs** are qualified to 1,000 temperature cycles at full operating power, as opposed to 100...

...make the connection between the vertical LED chips and the leads makes these surface-mount **LEDs** capable of withstanding high-temperature wave soldering. This **increases** manufacturing throughput and allows through-the-wave (TTW) techniques for **increased** production efficiency. Hewlett-Packard Company is a leading global manufacturer of computing, communications and measurement...